The Astrophysical Journal Letters, 716:L125–L130, 2010 June 20 doi:10.1088/2041-8205/716/2/L125

MERGING AND CLUSTERING OF THE *SWIFT* BAT AGN SAMPLE

Michael Koss[1,2], Richard Mushotzky[1], Sylvain Veilleux[1], and Lisa Winter[3]
[1] Astronomy Department, University of Maryland, College Park, MD, USA; mkoss@astro.umd.edu
[2] Astrophysics Science Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA
[3] Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, CO, USA
Received 2010 March 4; accepted 2010 April 28; published 2010 May 27

ABSTRACT

We discuss the merger rate, close galaxy environment, and clustering on scales up to an Mpc of the *Swift* BAT hard X-ray sample of nearby (z <0.05), moderate-luminosity active galactic nuclei (AGNs). We find a higher incidence of galaxies with signs of disruption compared to a matched control sample (18% versus 1%) and of close pairs within 30 kpc (24% versus 1%). We also find a larger fraction with companions compared to normal galaxies and optical emission line selected AGNs at scales up to 250 kpc. We hypothesize that these merging AGNs may not be identified using optical emission line diagnostics because of optical extinction and dilution by star formation. In support of this hypothesis, in merging systems we find a higher hard X-ray to [O III] flux ratio, as well as emission line diagnostics characteristic of composite or star-forming galaxies, and a larger *IRAS* 60 μm to stellar mass ratio.

Key words: galaxies: active – galaxies: interactions – X-rays: galaxies

Online-only material: color figure

1. INTRODUCTION

Simulations of the growth of black holes suggest that mergers of galaxies trigger the active galactic nucleus (AGN) phenomenon (Di Matteo et al. 2005). Tidal torques produced during the galaxy interaction send gas into the nuclear region to feed the black hole and enhance AGN activity (Domingue et al. 2005). Later in the merger phase the two supermassive black holes coalesce and a rapid accretion phase is entered with a burst of star formation before settling into a relaxed state.

The observational evidence for mergers driving AGN activity has been contradictory and seems to depend on the luminosity of the AGN. Clear evidence for higher incidence of mergers is seen among QSOs (Serber et al. 2006; Veilleux et al. 2009a). Early studies of the environment of Seyfert galaxies also appeared to show an excess of close companions (Petrosian 1982), but recent studies of typical AGNs have found no evidence for higher rates of mergers or close companions (Miller et al. 2003). For instance, X-ray studies of AGNs at intermediate redshifts did not find increased levels of mergers or close neighbors (Grogin et al. 2005). Host galaxies of AGNs in the COSMOS survey do not have greater numbers of nearest neighbor galaxies or disturbed morphologies compared to normal galaxies (Gabor et al. 2009). Finally, Li et al. (2006) analyzed 90,000 local (z <0.1) optically selected narrow-line AGNs from the Sloan Digital Sky Survey (SDSS) and found that only 1 in 100 AGNs has an extra neighbor within 70 kpc when compared to a control sample. At larger scales between 100 kpc and an Mpc, AGNs were clustered more weakly than normal galaxies.

The *Swift* Burst Alert Telescope (BAT) all sky hard X-ray sample of AGNs is uniquely suited to test whether local AGNs are found in mergers or with close companions that may be driving their AGN activity because it is conducted in the 14–195 keV energy band. This band is optically thin to much of the dust and gas obscuring the AGN and thus does not suffer from many of the biases of optical emission line classification of AGNs.

The BAT survey has identified 461 objects of which 262 are AGNs (Tueller et al. 2010). Most of the AGNs are quite close with a median redshift of ≈0.03. The 22 month BAT survey has a sensitivity of $\approx 2.2 \times 10^{-11}$ erg cm^{-2} s^{-1}, about 10 times more sensitive than the previous all-sky hard X-ray survey (HEAO 1 A-4). Higher angular resolution X-ray data for every source from either the *Swift* X-ray Telescope or archival data have allowed associations to be made with known counterparts in other wavelength bands for over 90% of the BAT detections. About 15% of the AGNs are newly discovered, having never been detected before as AGNs at other wavelengths. Recent studies of the sample have indicated that it may have increased rates of mergers. For instance, Schawinski et al. (2009) found an excess of residuals in the images after galaxy model subtraction with GALFIT for 16 BAT AGNs. Winter et al. (2009) also found 33% of BAT galaxies as peculiar or disturbed galaxies based on visual inspection of the 9 month survey.

This Letter revisits the issue of mergers driving AGN activity using an expanded sample of 181 BAT-detected AGNs. Section 2 describes our imaging and spectroscopic data and the analysis technique for measuring the incidence of nearby companions. Section 3 describes our results and whether merging galaxies may have higher levels of optical extinction or dilution by star formation, and finally the results are summarized in Section 4.

2. DATA AND ANALYSIS

For our analysis, we considered three samples. We studied a sample of BAT-detected AGN galaxies, a control sample of inactive galaxies from the SDSS matched to the BAT sample, and finally a sample of type 2 Seyferts from the SDSS matched to the BAT sample. We will henceforth refer to the three samples as BAT AGN, the control sample, and SDSS AGN, respectively. Our BAT AGN sample consists of nearby ($z < 0.05$) AGNs included in the 9 and 22 month catalogs (Tueller et al. 2010), as well as newly detected sources in the 58 month catalog (W. Baumgartner et al. 2010, in preparation). The total sample includes 181 BAT-detected AGN host galaxies, ≈90% of the entire northern hemisphere AGN sample. For our sample, we use a combination of archived imaging data from the SDSS DR7 as well as our own imaging observations taken over 17 nights at the Kitt Peak 2.1 m telescope in the *ugriz* SDSS bands. In this BAT AGN sample, 72/181 galaxies have spectral and imaging coverage of galaxy neighbors in the SDSS. We used these

72 BAT AGNs to compare to the other two samples. We subtracted the AGN contribution using GALFIT (Peng et al. 2002) for the broad-line AGN in the SDSS and Kitt Peak (M. Koss et al. 2010, in preparation) images for the broad-line AGN in the BAT sample.

We generated a control sample of inactive galaxies to compare apparent merger rates. Recent studies have found that merger rates are strongly linked to stellar mass and star formation. Geller et al. (2006) found increased star formation with smaller galaxy separation. In addition, Patton & Atfield (2008) found that at least 90% of all major mergers occur between galaxies which are fainter than L*. Therefore, to construct our control sample we used galaxies in the SDSS that have matched stellar masses, $g - r$ colors (as a proxy for star formation), and redshift. From the comparison sample we excluded broad-line AGNs using the SDSS galaxy class and narrow-line AGNs using the Garching catalog (Kauffmann et al. 2003). We also limited the redshifts to $z > 0.01$ because of the tendency of the automated SDSS photometry to shred bright galaxies into multiple components. We selected two matched control galaxies for each of the 72 BAT AGNs for a total size of 144 control galaxies.

We also used a sample of emission line selected AGNs in the SDSS for comparison, which we refer to as the SDSS AGN. Winter et al. (2010) found that the majority (75%) of a sample of 64 BAT AGNs were Seyferts. We therefore chose a sample of type 2 Seyferts from the Garching catalog using the emission line diagnostics of Kewley et al. (2006). We matched each of the 72 BAT AGNs to the SDSS Seyfert sample in terms of color, stellar mass, and redshift for a total of 72 SDSS AGNs.

We applied the same analysis technique to each of the three samples. To determine stellar masses, we used the software kcorrect (Blanton & Roweis 2007) with the *ugriz* photometry. To determine the redshifts of possible companion galaxies, we used the spectroscopic sample from the SDSS DR7. Since there is a 55″ fiber collision limit in the SDSS, as well as apparent magnitude limits for the spectroscopic survey, we supplemented our spectroscopic data for companions. We added any spectroscopic data of galaxy companions publicly available through NED closer than a projected separation of 30 kpc. In the range of 30 kpc–1 Mpc, we only used the redshifts of galaxy companions in the SDSS. Throughout this work, we adopt the following cosmological parameters to determine distances: $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 70$ km s^{-1} Mpc^{-1}. We define apparent mergers as galaxies that show close physical pairs (with a real-space separation of <30 proper kpc) or clear signs of a disturbed morphology such as tidal tails or bridges between galaxies based on visual inspection of three-color images.

We measured the closest companion to each member of our BAT AGN, control, and SDSS AGN samples on scales up to 1 Mpc. To decide whether the neighboring galaxy is at the same radial distance, we followed the criteria of Patton & Atfield (2008) and used radial velocity differences of less than 500 km s^{-1} between the sample galaxy and its possible companion. We also looked at the *gri* composite image of each galaxy for signs of recent mergers such as tidal tails, binary nuclei, and disturbed morphologies.

3. RESULTS

We find that 18% (13/72) of the BAT AGN galaxies have disturbed morphologies consistent with a recent merger. Another 4 BAT AGNs (6%) are in close physical pairs with separations of 20–30 kpc, where tidal effects are considerably weaker. Finally, one additional BAT AGN (1%) shows a single nucleus with signs of tidal tails. The overall fraction of BAT AGN undergoing mergers is therefore 25% (18/72). A full listing of the BAT AGN galaxies in apparent mergers is in the top panel of Table 1. In Figure 1, we show images of nine of these galaxies selected at random from Table 1. In the control sample, we find only 1% in apparent mergers and for the SDSS AGN sample we find 4%. This small rate is consistent with that of Patton & Atfield (2008) who found merger rates of 2% for normal galaxies at similar distances and cosmology and other studies that have found no differences in merger rates between optically selected AGN and normal galaxies.

We also searched for galaxy companions to BAT AGN outside of the SDSS spectroscopic sample using NED. For the 109 BAT AGN with images and spectra obtained at Kitt Peak, we find a lower rate of 22/109 or 20% in apparent mergers. This lower number is expected because of the reduced number of spectra of galaxy companions in NED. A listing of these BAT AGNs in apparent mergers is in the bottom panel of Table 1.

Application of our technique to an independent sample of INTEGRAL-selected AGNs detected in the hard X-rays ($z < 0.05$; Beckmann et al. 2009) in the northern hemisphere finds a similar rate of 28% (15/53) in apparent mergers with companions within 30 kpc or in disrupted systems.

In addition, we looked for faint companions to BAT AGN in the SDSS photometric catalog with no spectroscopy. We looked specifically at the magnitude difference between the galaxy and its possible companion. Within 30 kpc we find no additional close companions within 2 mag of the host galaxy for the BAT AGN, but an additional 1% for the SDSS AGN, and 2% for the control sample. Between 2 and 3 mag, we find 4% for the BAT AGN sample, 3% for the control sample, and 3% for the SDSS AGN. These faint galaxies could be at higher redshifts, and the small percentage indicates we miss only a small number of true faint companions.

We use the approach of Bell et al. (2006) for a rough estimate of the number of mergers per Gyr to assess the incidence of mergers. They estimate a typical merger timescale of 0.4 Gyr for a merger of two equal mass galaxies of radius 15 kpc that are within a distance of <30 kpc of each other. Mergers of unequal masses will tend to take longer because of reduced dynamical friction, so Bell et al.'s approach provides an upper limit on the merger rate. Following this method, the merger rate per Gyr is the percentage of galaxies in apparent mergers divided by 0.4 Gyr or about 63% per Gyr for the BAT AGN. This suggests that galaxy merging may be an important mechanism to power the AGN.

Next, we looked for the presence of companions on larger scales, between 30 kpc and 100 kpc. The cumulative distribution of nearest companion galaxies within 100 kpc can be found in Figure 2, left. The mean nearest neighbor galaxy separations are 41 ± 28 kpc, 72 ± 18 kpc, and 61 ± 24 kpc for the BAT AGN, control galaxies, and SDSS AGN sample, respectively. For galaxies with companions within 100 kpc, a Kolmogorov–Smirnov (K-S) test indicates a <5% chance that the distribution of nearest neighbor distances for the BAT AGN is from the same parent distribution as the control galaxies or SDSS AGN. This indicates that the BAT AGNs have, on average, more and closer companions than the control or SDSS AGN galaxy on scales less than 100 kpc. We confirm that SDSS AGN and normal galaxies have similar clustering and apparent merger rates (e.g., Li et al. 2006): a Kuiper test of the SDSS AGN and

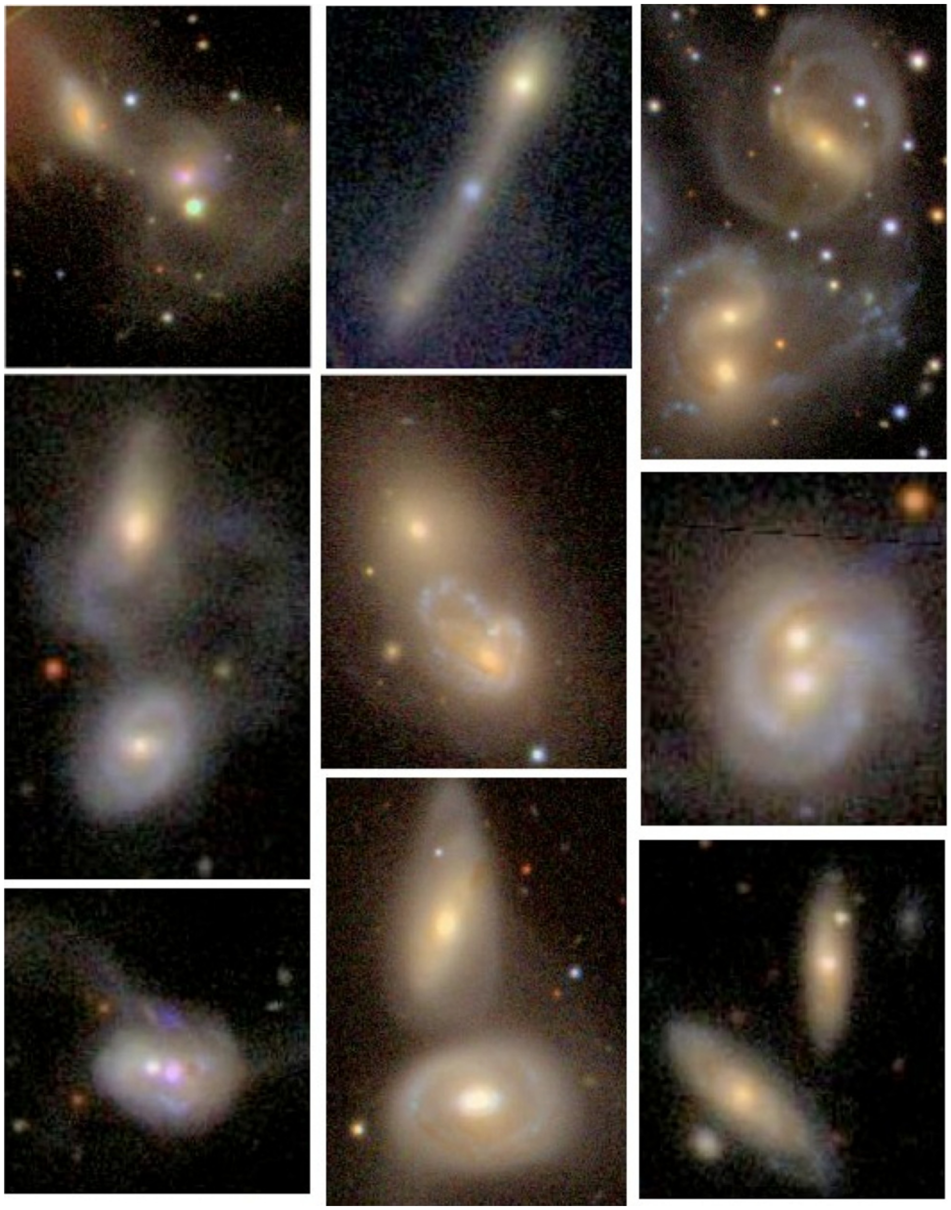

Figure 1. Composite *gri* filter images of BAT AGN hosts with disturbed morphologies or companions within 30 kpc from the SDSS and Kitt Peak. The nine galaxies were selected at random from the 40 galaxies in Table 1. An arcsinh stretch was used as described in Lupton et al. (2004) with intensity scaled by flux.

(A color version of this figure is available in the online journal.)

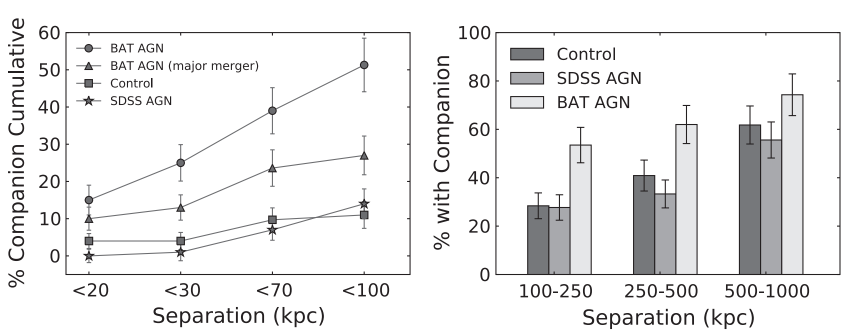

Figure 2. Left: cumulative distributions of BAT AGN, control galaxies, and SDSS AGN with nearest neighbors identified in the SDSS survey as a function of physical separation in kpc. The error bars assume Poisson statistics. The filled circles indicate BAT AGN with any galaxy companion. The triangle line is for AGNs with a companion galaxy that has a stellar mass within a factor of 10 of the galaxy and may be considered a major merger. We find a much higher fraction of BAT AGNs with close companions on scales <100 kpc. Right: fraction of BAT AGNs, control galaxies, and SDSS AGNs with companions with projected physical separations of 100–1000 kpc. An excess of companions at 100–250 kpc is seen among BAT AGNs.

Table 1
BAT AGNs in Apparent Mergers

Galaxy Name[a]	z	$\log \frac{M^*}{M_\odot}$ [b]	Dist (kpc)[c]	Disruption[d]	Companion[e]	Notes[f]
2MASX J09043699+5536025	0.037	10.4	9	X	2MASX J09043675+5535515	SDSS
ARP 151	0.021	9.6	10	X	SDSS J112535.23+542314.3	SDSS
KUG 1208+386	0.023	10	24		2MASX J12104784+3820393	SDSS
MCG +06-24-008	0.026	10.2	30		SDSS J104444.22+381032.9	SDSS
Mrk 0739E	0.03	10.4[g]	2	X	NGC 3758	SDSS
Mrk 1018	0.043	9.7	...	X	...	SDSS
Mrk 110	0.035	10	...	X	Foreground star?, tidal tail	SDSS
Mrk 463E	0.05	10.6[g]	4	X	Mrk 463W	SDSS
Mrk 477	0.038	9.9	19	X	SBS 1439+537	SDSS
NGC 0835	0.013	10.5	15	X	NGC 833	SDSS
NGC 1142	0.029	10.7	17	X	SDSS J025512.06-001032.9	SDSS
NGC 5106	0.032	10.6	25	X	NGC 5100 NED01	SDSS
NGC 985	0.043	10.6	2	X	NGC 0985 NED02	SDSS
UGC 03995	0.016	10.6	9	X	UGC 03995 NOTES01	SDSS
UGC 05881	0.021	10.8	24		SDSS J104644.87+255502.1	SDSS
UGC 06527 NED03	0.026	10.5	24	X	UGC 06527 NED02	SDSS
UGC 07064	0.025	10.2	30		CGCG 158-011 NED01	SDSS
UGC 08327 NED02	0.037	10.9	35	X	UGC 08327 NED01	SDSS
2MASX J00253292+6821442	0.012	10.1	3	X	...	
2MASX J11454045-1827149	0.033	10	14	X	LEDA 867889	
2MASX J17232511+3630257	0.04	10.35	21		2MASX J17232321+3630097	
ESO 490-IG026	0.025	10.7	...	X	...	
FAIRALL 0272	0.022	10.3	19	X	FAIRALL 0271	
IRAS 05589+2828	0.033	10.4	8	X	2MASX J06021038+2828112	
M106	0.002	9.9	24		NGC 4248	
MCG +04-48-002	0.014	10.2	24		NGC 6921	
MCG -02-12-050	0.036	10.7	33	X	2MASX J04381113-1047474	
Mrk 279	0.03	10.5	27	X	MCG +12-13-024	
Mrk 348	0.015	10.3	22		2MASX J00485285+3157309	
Mrk 520	0.026	10.4	...	X	...	
NGC 235A	0.022	9.9	9	X	NGC 0235B	
NGC 2992	0.008	10.3	20	X	ARP 245N	
NGC 3227	0.004	10	10	X	NGC 3226	
NGC 3786	0.009	10	14	X	NGC 3788	
NGC 5506	0.006	10	17		SDSS J141324.11-031155.8	
NGC 6240	0.024	11[g]	0.9[h]	X	...	
NGC 7319	0.022	10	11	X	Stephan's Quintet	
NGC 7469	0.016	10.5	25		IC 5283	
NGC 931	0.017	10.6	6	X	UGC 01935 NOTES01	
UGC 11185 NED02	0.041	10.2	24	X	UGC 11185 NED01	
2MASX J04234080+0408017	0.048	10	6	X	...	Uncertain
3C 111.0	0.048	10	24		2MASX J04181911+3801368	Uncertain

Notes.
[a] The top section includes BAT AGN in apparent mergers (18/72) that was compared to the SDSS AGN and control sample. The bottom section includes apparent mergers in the Kitt Peak sample (22/109) with spectroscopic coverage of companions only from NED.
[b] Host galaxy stellar mass based on using *ugriz* photometry and the kcorrect software of Blanton & Roweis (2007).
[c] Distance to nearest galaxy companion.
[d] Signs of disruption consistent with a merger.
[e] NED name where available.
[f] SDSS: in the SDSS spectroscopic sample, uncertain: Companion is within 2 mag of the *J*-band filter magnitude of BAT AGN galaxy, but has no spectroscopic redshift.
[g] Galaxy nuclei are too close to accurately separate galaxies for stellar mass.
[h] Based on a recent *Chandra* observation.

control galaxies gives an 87% chance that both samples are taken from the same parent population.

We also determined the fraction of galaxies with neighbors between 100 kpc and 1 Mpc. A K-S test of the distribution of closest companions within 250 kpc yields a likelihood of $<1\%$ that the distributions of BAT AGN and control galaxies or SDSS AGN are from the same parent population. A Kuiper test indicates that there is less $<5\%$ probability that the BAT AGN companion galaxy distances are from the same parent population as the control sample or SDSS AGN. In addition, a statistically higher percentage of BAT AGNs have neighbors at 100–250 kpc compared to the control or SDSS AGN (Figure 2, right). All of these statistical tests indicate that the BAT AGNs have closer companions than the control or SDSS AGN sample on scales less than 250 kpc.

Next, we examined the optical spectra of the BAT AGN in more detail to test whether the hard X-ray method may be selecting different types of AGNs compared to the optical

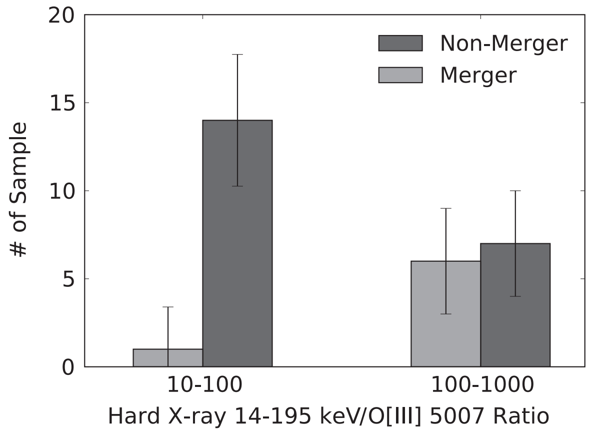

Figure 3. Histogram of the hard X-ray to [O III] λ5007 ratio for broad-line BAT AGNs. In order to mitigate possible systematics effects associated with the different instrument configurations of the various surveys, we averaged the [O III] flux measurements from the different surveys before calculating the X-ray to [O III] ratios. A K-S test indicates a 3% chance that the distributions of non-mergers and mergers are taken from the same parent population.

emission line classification. Optical fluxes were corrected for galactic extinction based on Balmer decrements and were taken from Winter et al. (2010), Ho et al. (1997), and the Garching catalog of reduced optical spectra. The total sample includes 29 broad-line and 45 narrow-line BAT AGNs. We examined the distribution of the hard X-ray to [O III] λ5007 ratio for the non-merging and merging broad-line AGNs (Figure 3) and found that all but one of the merging broad-line AGNs, NGC 3227, are in the higher X-ray to optical ratio bin. Merging and non-merging systems have similar hard X-ray luminosity distributions so this larger X-ray to [O III] ratio in merging systems is attributed to an [O III] deficit, possibly due to unaccounted optical extinction.

In the case of narrow-line AGNs, we find that merging galaxies do not have higher hard X-ray to [O III] ratios than non-merging galaxies. The mean hard X-ray to [O III] ratio is about 10 times larger for the narrow-line compared to the broad-line AGN, though, so other factors may have a stronger influence on the ratio such as the amount of narrow-line region gas, the geometry of the torus, the scattering fraction, or different levels of absorption of the hard X-ray flux for these objects. This higher hard X-ray to [O III] ratio among narrow-line AGNs contradicts the AGN unification model, unless the [O III] flux is affected by orientation effects and/or is severely underestimated due to extinction.

We also looked to see if a disproportionate fraction of merging systems are missed as AGNs using optical emission line diagnostics. Using the classification scheme of Kewley et al. (2006) we find that 19% of the non-merging BAT AGNs are classified as composite or H II region-line galaxies rather than AGNs. In galaxies undergoing a merger we find a rate of 33%. The lower merger rate in the SDSS AGN sample may therefore be due to the fact that the optical emission line classification is biased against mergers.

Elevated star formation activity could dilute the AGN emission, causing the AGN to be missed using optical emission line classification. We therefore investigated the *IRAS* data (Moshir et al. 1992) to see if the level of star formation in the merging systems was higher than the non-merging systems (Figure 4). The 60 μm is a useful tracer of strong bursts of recent star formation and is less affected by AGN emission. We define the specific star formation rate as the logarithm of the ratio of 60 μm emission to stellar mass.

The mean of the specific star formation rate for merging systems is higher (30.59 ± 0.42 erg s^{-1} $M_{\odot}^{-1}$) than for non-merging systems (30.34 ± 0.57 erg s^{-1} $M_{\odot}^{-1}$). A K-S test indicates a 2% chance that the distribution of star formation ratios for merging and non-merging galaxies is the same. A Kuiper test has a 10% chance. If we include upper limits of the *IRAS* flux, a Kuiper test indicates a 7% chance. These statistical tests indicate enhanced star formation activity in merging systems compared to non-merging systems.

To further investigate the possibility that BAT AGNs are found in galaxies with higher merger rates than average, we looked at the level of star formation activity based on the *IRAS* 60 μm emission in BAT AGNs compared to normal galaxies in the control sample and redshift-matched SDSS AGN. A larger fraction of the BAT AGNs (61%) are detected at 60 μm than normal galaxies in the control (14%) and SDSS AGN (11%). We also find that 18% of the BAT AGNs are luminous infrared galaxies (LIRGS;$L_{\mathrm{IR}} > 10^{11} L_{\odot}$) and only 3% of the control galaxies and 1% SDSS AGN are LIRGs. These results indicate that BAT AGNs have elevated star formation activity relative to normal galaxies and SDSS AGN (AGN contamination to the 60 μm emission in LIRGs is negligible; Petric et al. 2010).

4. SUMMARY AND DISCUSSION

We find a larger fraction of BAT AGNs with disturbed morphologies or in close physical pairs (<30 kpc) compared to matched control galaxies or optically selected AGNs. The high rate of apparent mergers (25%) suggests that AGN activity and merging are critically linked for the moderate luminosity AGN in the BAT sample. We also investigated why this merging rate is larger than in optical AGN samples. We find that merging

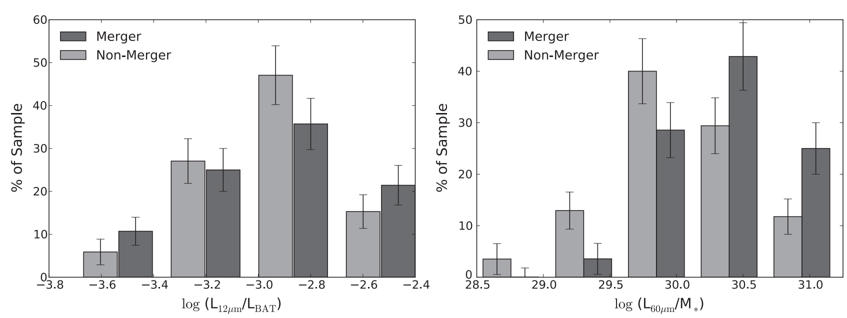

Figure 4. Left: histogram of the *IRAS* 12 μm to hard X-ray emission ratio for merging and non-merging BAT AGNs. The sample includes 28 mergers and 85 non-mergers. No difference is observed between merging and non-merging systems. Most systems have $L_{12\mu\mathrm{m}}/L_{\mathrm{BAT}} \approx 0.1\%$, confirming the known strong correlation between the mid-IR and hard X-ray emission (e.g., Vasudevan et al. 2010). Right: histogram of the logarithm of the ratio of 60 μm emission to stellar mass. This ratio is larger on average among merging systems, indicating enhanced star formation in these systems.

broad-line AGN galaxies are preferentially found in galaxies with high hard X-ray to [O III] λ5007 ratios. We also find a higher specific star formation rate in merging systems in the BAT sample. This suggests that these merging AGNs may not be identified using optical emission line diagnostics because of optical extinction and dilution by star formation. Additional support for this picture comes, for instance, from Goulding & Alexander (2009) who found that optical emission line classification may be missing 50% of local AGNs identified via mid-infrared spectroscopy with *Spitzer*. This also seems to be the case at slightly higher redshifts and luminosities among ULIRGs ($L_{\rm IR} > 10^{12}\ L_\odot$; Veilleux et al. 2009b).

Facilities: Swift, Sloan, KPNO:2.1m, IRAS

REFERENCES

Beckmann, V., et al. 2009, A&A, 505, 417
Bell, E. F., Phleps, S., Somerville, R. S., Wolf, C., Borch, A., & Meisenheimer, K. 2006, ApJ, 652, 270
Blanton, M. R., & Roweis, S. 2007, AJ, 133, 734
Di Matteo, T. D., Springel, V., & Hernquist, L. 2005, Nature, 433, 604
Domingue, D., Sulentic, J., & Durbala, A. 2005, AJ, 129, 2579
Gabor, J. M., et al. 2009, ApJ, 691, 705
Geller, M., Kenyon, S., Barton, E., Jarret, T., & Kewley, L. 2006, AJ, 132, 2243
Goulding, A. D., & Alexander, D. 2009, MNRAS, 398, 1165
Grogin, N. A., et al. 2005, ApJ, 627, L97
Ho, L. C., Filippenko, A. V., & Sargent, W. L. W. 1997, ApJS, 112, 315
Kauffmann, G., et al. 2003, MNRAS, 341, 33
Kewley, L. J., et al. 2006, MNRAS, 372, 961
Li, C., Kauffmann, G., Wang, L., White, S. D. M., Heckman, T. M., & Jing, Y. P. 2006, MNRAS, 373, 457
Lupton, R., Blanton, M., Hogg, W., Fekete, G., O'Mullane, W., Szalay, A., & Wherry, N. 2004, PASP, 116, 133
Miller, C. J., Nichol, R. C., Gómez, P. L., Hopkins, A. M., & Bernardi, M. 2003, ApJ, 597, 142
Moshir, M., et al. 1992, IRAS Faint Source Survey, Version 2, JPL D-10015 (Pasadena, CA: JPL)
Patton, D. R., & Atfield, J. E. 2008, ApJ, 685, 235
Peng, C. Y., Ho, L. C., Impey, C. D., & Rix, H.-W. 2002, AJ, 124, 266
Petric, A., et al. 2010, ApJ, submitted
Petrosian, A. R. 1982, Afz, 18, 548
Schawinski, K., Virani, S., Simmons, B., Urry, C. M., Treister, E., Kaviraj, S., & Kushkuley, B. 2009, ApJ, 692, L19
Serber, W., Bahcall, N., Ménard, B., & Richards, G. 2006, ApJ, 643, 68
Tueller, J., et al. 2010, ApJS, 186, 378
Vasudevan, R., Fabian, A. C., Gandhi, P., Winter, L. M., & Mushotzky, R. F. 2010, MNRAS, 402, 1081
Veilleux, S., et al. 2009a, ApJ, 701, 587
Veilleux, S., et al. 2009b, ApJS, 182, 628
Winter, L. M., Lewis, K. T., Koss, M., Veilleux, S., Keeney, B., & Mushotzky, R. 2010, ApJ, 710, 503
Winter, L. M., Mushotzky, R., Reynolds, C., & Tueller, S. 2009, ApJ, 690, 1322